Contents

4 End Use Energy Efficiency

4.1 Introduction

4.1.1 Review of Screening Study

The preliminary screening analysis identified end-use efficiencies (including electrical lighting, refrigerator/freezers, appliances, new space heating, and new water heating) as a potential source of economic benefits for rural households.

4.1.2 This Study

4.1.2.1 Scope

This study examines end-use energy efficiency in rural Alaska households and rural schools in communities that are eligible for Power Cost Equalization (PCE) Funding.

Of the roughly 29,000 rural Alaska households identified in the 2000 Census, it appears that nearly 25,000 of those households participated in the PCE program in FY00.

Average electrical consumption is estimated at 420 kWh a month (5,040 kWh/year) and average heating fuel consumption at 700 gallons a year.

Thus in aggregate, rural Alaska *households* consume roughly:

Electricity	126,000,000 kWh/year	$38.7 million/year	
		Less	$16 million/year PCE
		Net	$22 million/year
Heating Fuel	17, 500,000 gallons/year	$26 million/year	
		Less	$ 9 million/year LIHEAP
		Net	$17 million/year

It appears that roughly 4.1 million square feet of school buildings existing in the PCE eligible communities in rural Alaska. Based on anecdotal evidence, the average electrical consumption is estimated at 12kWh/square foot/year.[1] Average heating fuel consumption is estimated at 1.2gallons/square foot/year.

Thus, in aggregate, rural Alaska school buildings consume roughly:

Electricity	49,200,000 kWh/year	$14.8 million/year
Heating Fuel	5,000,000 gallons/year	$ 7.5 million/year

[1] It also appears that average households use about 5 to 8 kWh/day per person in the winter months.

4.1.2.2 Objective

The objective of this study is to evaluate the costs and benefits of end-use energy efficiency systems that are suitable for rural Alaska and determine the extent to which these systems could potentially reduce the cost or improve the reliability of electricity for rural communities. In addition, this study reviews program implementation alternatives with the goal of maximizing program effectiveness.

4.1.2.3 Key Evaluation Considerations

This study distinguishes between the engineering economic potential and *market potential* of end-use energy efficiency measures in rural Alaska.

The engineering economic potential of an efficiency measure is a calculation of the costs that are likely to be avoided if the measure is adopted. For example, if a household installs a new compact florescent light bulb replacing an incandescent light bulb, the household will pay more for the light bulb up front, but may save hundreds of kilowatt hours over the life of the new light bulb which lasts around 10 times as long as the incandescent light bulb. The net economic effect of the more expensive, but more efficient, longer lasting compact florescent may to save the household on the order of $100 over roughly 3 years.[2]

The market potential is an estimate of the number of households (and light bulbs per household) that will participate in the bulb replacement program who would otherwise not have replaced bulbs. For example, without any additional bulb replacement program, 5 percent of rural households may replace incandescent bulbs in any given year. With a new light bulb replacement program, 13 percent of rural households may replace incandescent bulbs over the course of the program. The *net* market potential of the program is the difference between the bulb replacements that may occur *with* the program (13 percent) and the bulb replacements that would occur *without* the program (5 percent), for a net market potential of 8 percent of rural households.

Detailed examples of the engineering and market potential of end-use energy efficiency measures are developed below.

The narrative will develop examples of light bulb replacement programs. The appendices will develop examples of energy efficient appliances.

4.1.2.4 <u>Engineering Economic Potential</u>

The engineering economic potential is represented by the traditional total life cycle cost comparison between the estimated cost of two alternatives that provide comparable levels of service.

When comparing the life cycle costs of incandescent and compact florescent light bulbs, the cost includes the purchase price of the bulbs and the cost of energy.

The purchase price of bulbs is estimated based on light bulb choices commonly available at retail outlets in Alaska.

What is the cost of energy?

The price paid by the household for energy consumption (average price per kilowatt hour) is one measure of the cost of energy. In the absence of a subsidy (like PCE), this represents the direct costs that the household experiences. In the presence of a subsidy (like PCE), the net effect of the subsidy

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[2] $100 over 3 years works out to roughly $0.09 per day. This is roughly equivalent to a regular cup of coffee about once every ten days, or a “designer” cup of coffee about once a month.

may be to reduce the incremental cost of electricity to the household to some fraction of the average price, effectively reducing economic incentives to adopt more energy efficient measures. The cost of energy has been shifted from the household to the subsidy program.

Another measure of the cost of energy is the overall incremental cost to the system that results if an individual household reduces its energy consumption through the use of a more efficient light bulb. While the monthly bill to the household (without PCE) may be reduced by the average price of electricity, the utility only saves the incremental basic avoided costs (fuel savings from having to produce fewer kWhs plus fewer hours on diesels, delaying potential overhaul costs). The relatively fixed costs of overhead (customer service, meter reading, billing personnel) remain to be spread out over fewer kWhs. In the short term, this typically results in a reduction in the utility's margins. In the intermediate term, this may cause the utility to raise the per kWh rate to cover its fixed costs. In the long term, the utility may try to reduce its fixed costs.

Here, we are interested in the cost of energy from two perspectives:

- Perspective of the individual household with and without a subsidy (PCE)
- Perspective of the utility and how the savings of one household may affect the system of households connected to the utility

The individual household perspective sheds some light on the economic incentives faced by individual households and their relative propensity to seek more or less efficient end-use measures. With PCE, the relative incremental propensity for households to seek out energy efficiency is low. Nonetheless, the high average bill of rural households (ranging up to 6 to7 percent of median household income) for electricity does provide them with the perception that energy efficiency measures and reduced consumption should be helpful in reducing their overall average bill.

The utility system perspective illuminates the potential system savings and costs that can be shared by all households connected to a particular system. The overall utility system perspective is adopted in this analysis to assess the net potential economic benefits to the system of an end-user conservation measure and to be able to compare the relative economic value to supply side energy efficiency measures. The overall net economic benefits may be shared between a participating household, a non-participating household, and the utility, its managers, employees, and owners.

The utility system costs that might be avoided when households replace incandescent light bulbs with CFLs vary significantly depending upon the rural community. In most cases, less diesel fuel is burned to generate kWhs and overhauls can be delayed. In some cases, where a new diesel gen set or a new fuel storage system is under consideration, the required capacity of those systems may be reduced to reflect less overall need with a more efficient system. Developing some illustrative examples from rural Alaska communities, the basic avoided cost may range from roughly 10 cents per kWh to over 20 cents per kWh. Taking into account the potential for avoiding diesel and fuel storage capacity, the potential avoided costs may range from roughly 15 cents per kWh to around 30 cents per kWh.

Table 4-1. Avoided Costs (cents per kWh)

	Avoided Fuel Cost	Avoided O&M Cost	Basic Avoided Cost	Potential Fuel Storage Savings	Potential Diesel Capacity Savings	Potential Avoided Costs
Hooper Bay	10	2	12	3	3	18
Golovin	13	3	**16**	3	3	22
Buckland	20	2	22	5	3	30

In the illustrative examples developed below, the **basic** avoided cost of 16 cents per kWh from Golovin is used.

In cases where the end-use efficiency measures are being considered in conjunction with new tank farms and new diesels and capacity in those systems can be avoided, the higher values associated with the **potential** avoided costs column may be more appropriate.

Table 4-2. Simple Engineering Economic Savings Estimate of Lighting—Golovin Illustrative Example

Equivalent Lumens =	27 Watt Compact Fluorescent	100 Watt Incandescent
Cost of Bulb	$6.00	$0.40
Lamp Life[3]	8,000	750
Lamp Life (Avg. 8 hours/day)	1000 days	94 days
	2.74 years	0.26 years
Capital Cost over 2.74 years (8,000 hours)	$6.00	$4.26
Rural Alaska Avg. *Cost* of Energy	$0.16/kWh	$0.16/kWh
Total Energy Use over 2.74 Years (8,000 hours of use)	216 kWh	800 kWh
Lifetime Energy Cost[4]	$34.56	$128.00
Total Cost	$40.56	$128.40
Fluorescent Savings	**$87.84 per incandescent bulb replaced by CFL**	

Assuming 25,000 rural households, and **seven** incandescent bulbs that could be replaced with small compact fluorescents, the aggregate simple savings could be as much as:

$615 per household X 25,000 households = $15.4 million (over 2.74 years)
$ 5.6 million (per year)
$224 per household per year

[3] While CFL packaging suggests lamp life "up to 10,000 hours," Consumer Reports indicates that many CFLs do not appear to achieve a mean lamp life of 10,000 hours.

[4] Undiscounted lifetime energy cost is used to reflect the most common calculations provided in government and marketing literature. In addition, a quick survey of households suggests that well over 90 percent of the households that might stop to compare the initial cost of a bulb and its potential energy savings do not *directly* discount the potential future energy savings. Household discount rates are briefly discussed below in the "market potential" section.

Given the tremendous economic savings that appear to be available by replacing light bulbs, why does our recent (2001) survey suggest that, on average, rural Alaska households have three compact fluorescent bulbs and eight incandescent bulbs?

Buyers of light bulbs may simply be influenced by several factors other than the *simple life cycle cost analysis*.

What else may be happening?

4.1.2.5 Market Potential

Despite what appears to be extremely favorable engineering economics, customers *may* not purchase the apparent "most economic" alternative. Additional considerations include:

- High first cost of CFLs compared to incandescent bulbs (On the order of 20:1)
  - In a large discount store in Anchorage, the money to buy CFLs for *one* rural household (7 * $5/each = $35) will buy incandescent bulbs for *20* rural households ($35 ÷ $0.25 = 140 bulbs; ÷ 7 bulbs/household = 20 households).[5]
  - Lower income households tend to be more sensitive to first cost than higher income households. Given less cash on hand, there is a tendency to buy the low initial cost product. This results in a high "implicit discount rate"[6] for lower income households.
- Households may have limited knowledge or conflicting information about the trade-offs between the first cost, energy costs, and performance of lighting systems.
- Concerns with compact fluorescent light (CFLs) bulb performance
  - Poor fit in existing fixtures if at all; concerns that CFLs may not be as bright as incandescent bulbs or the light is not as warm; non-standard appearance of CFLs; concerns that many CFLs cannot be used with dimmer circuits; concerns with limited availability of CFL replacement bulbs in rural communities (slow product diffusion); concerns with ability of CFLs to provide consistent performance when cold (outdoor ambient temperatures in rural Alaska are outside of many CFL operating temperature specifications).
- Studies reviewing data from the 1970s and 1980s, when households were faced with rapid increases in the price of electricity, indicate that households replaced incandescent fixtures with fluorescent fixtures in locations where the light was left on much of the day, i.e., kitchen. In other locations with lower hour per day usage, incandescent bulbs were apparently preferred for the quality of the light and because they did not require changing very often.[7] Similar phenomena may be occurring in today's market: 1) a change in price stimulates a change in behavior (either higher electricity costs or lower light bulb costs), 2) high hours-per-day usage area bulbs are replaced first.
- Households that have purchased CFLs may not experience dramatic savings in their monthly electrical bill, dampening enthusiasm for further CFL purchases given their high first cost.

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[5] $5 for CFLs and $0.25 for incandescent light bulbs based on recent COSTCO purchases (2002) in Anchorage. Actual landed cost in a rural village may vary, but the relative difference in price may be roughly comparable..

[6] See Hausman, Implicit Discount Rates for Energy Efficient Appliances.

[7] California Energy Commission, Lighting Market Study (2000).

  - o First, even under ideal circumstances, replacing an incandescent with a CFL in a high usage (12 hours/winter day) light fixture, the potential energy average price savings might amount to $4 a month. Under many circumstances, a rural household receiving PCE support might only see 50 cents of savings reflected on their monthly bill; the balance of the savings, $3.50, is captured by the PCE program in the form of lower PCE support to that household.
  - o Second, consumers often leave fluorescents on longer than incandescents.[8] This may be attributed to perceptions about the lower cost of energy and avoiding on/off cycles and the perception that CFLs might flicker more and have a shorter life if they are switched on and off frequently. In addition, if lights are installed in the fall or winter when households are likely to expand their overall electrical use, the *overall monthly bill* may still go up, so the savings due to the new, more efficient bulbs may not be readily noticeable.
- o Many stores have increased their stock of tourchier fixtures with halogen bulbs that have a first time price of $15 – creating a popular low first-cost alternative with a reputation for a "bright" light.

Thus, while the "economics" may appear favorable, households may have many factors under consideration when buying lighting. In addition, the savings associated with the new lighting may not appear significant.

Finally, while our snapshot survey of rural households suggests a market penetration of 33 percent for CFLs, anecdotal evidence from COSTCO and others is that, over the last 24 months, the volume of CFLs (especially "compact twist" type) sold in Alaska has increased as the average price per bulb in multiple bulb packages has continued to decline to well under $10.[9] The author has recently observed the twist CFLs in households in Barrow, Venetie, Napaskiak and Tuntutuliak— with the households reporting recent purchases from COSTCO.

These observations raise the question of how fast rural households buy energy efficient lighting without any additional market intervention.

For a simple example, 25,000 households X 7 incandescent bulbs/household = 175,000 bulbs. Assume that, absent any new market intervention program, around 5 percent of the remaining incandescent market will change over to CFLs in a given year (8,750 bulbs). Over four years, this would amount to an aggregate average of roughly one bulb per rural household.

How can that rate of incandescent replacement with CFLs be cost-effectively increased to those households that would benefit from CFLs, but currently do not buy them due to a "market failure"?

4.1.3 Program Design Considerations

In order for a rural light bulb replacement program to break even, the incremental benefit would have to exceed the incremental cost. For our example, if the "natural rate" of incandescent replacement is 5 percent and the new program was able to increase the rate to 8 percent (3 percent incremental market penetration benefit), how much could you spend before the program cost more than its potential savings? Over four years, 12 percent of the market (175,000 bulbs) = 21,000 bulbs X $88

[8] California Energy Commission, Lighting Market Study (2000).

[9] A General Electric Market Study cited in the literature suggested that a relatively modest decline in CFL price to the $5 - $10 per bulb range could trigger a demand increase of 250 percent.

life cycle cost savings per bulb = $1.8 million. Deducting the capital cost of the bulbs (21,000 X $5 (bulk purchase) = $105,000) leaves roughly $1.7 million available to pay for personnel, travel, freight, etc. In short, the first cost of CFLs is quite small compared to the energy savings over the life of the bulb.

4.1.3.1 No Growth Scenario

Some utilities have expressed concern that in low or no-growth markets with adequate generation capacity, a large investment in energy efficient light bulbs may have adverse effects by noticeably reducing demand and causing generating plants to operate lower on their fuel efficiency performance curve. This may result in some customers (who didn't participate in the bulb replacement program) paying more for their electricity than before.

What might the next effect be? Assume that a quarter of the incandescent light bulbs in a rural community of 180 households were replaced next year with CFLs.

- Existing Light Bulbs = 7 bulbs/house X 180 households = 1260 bulbs X ¼ = 315 bulbs
- Potential Reduction in Peak Load (Assuming 80 percent coincident peak) = 315 bulbs X 70 Watts/bulb X 0.8 coincident peak factor X 1.08 kWh generated per kWh sold = 19 kW generation
- Current peak = 500 kW
    - 3.8 percent reduction in peak load due to bulb replacement
    - Difference in diesel gen system performance = -0.3 kWh generated per gallon to 0.2 kWh generated per gallon depending upon diesel system[10]
- Annual kWh = 2,400,000 generated
    - 2,400,000 kWh divided by 12 kWh generated per gallon = 200,000 gallons
    - Reduction in annual demand due to bulb replacement (315 bulbs X 70 watt difference X 8 hours/day X 365 days/year = 64,386 kWh
    - 2,335,614 kWh divided by 12.0 kWh generated per gallon = 194,635 gallons
    - Net fuel *savings* = 5,366 gallons
    - However, the average price per kWh may change as a result of the decrease in kWhs sold due to:
        - A change in fuel efficiency due to operating at a lower fuel efficiency point on the diesel performance curve
            - $1.20 per gallon divided by 12.3 kWh generated per gallon = 9.756¢/kWh fuel cost
            - $1.20 per gallon divided by 12.0 kWh generated per gallon = 10.000¢/kWh fuel cost

[10] A review of fuel efficiency performance curves suggests that the peak fuel efficiency performance of a single gen set may be between 75 and 95 percent of its rated capacity with fairly gentle slopes on either side (until the unit load drops below 50 percent where fuel economy performance degrades rapidly). Thus, a 5 percent reduction in load can easily result in a relatively modest increase or decrease in fuel efficiency.

  - Thus, after PCE, a non-participating household may see a price increase of 15 percent X 25/1000ths of one cent per kWh due a change in diesel generation efficiency. Given a monthly consumption of 400 kWh, this could amount to an increase in the monthly bill of 10 cents.
- The same amount of fixed overhead being spread over fewer kWhs
  - Assume fixed overhead costs are roughly 28 cents per kWh X 2,400,000 kWh = $672,000 per year.
  - Spread the same amount of fixed overhead $672,000 over 2,335,614 kWh = 28.77 cents per kWh.
  - Adding this to the potential decline in efficiency, all other things being equal, 15 percent X one cent per kWh, this would amount to an increase of $4 on a monthly consumption of 400 kWh. Thus, a non-participating household might see a net increase of $48 over a year.

In rural Alaska communities where no new housing, no new water and sewer and no new school buildings are planned, there is some risk that non-participants in energy efficiency initiatives will see increases in their electricity rate and *gross* bill on the order of $48 over a year while participants may see $100-$200 in benefits over a year.

After factoring in how much of the bill is offset by PCE, the net customer bill of a non-participant may increase on the order of $5 over a year while participants may see benefits on the order of $10-$20 per year.

Some light bulb programs have often finessed this risk of increased costs to non-participants by making an effort to make sure all households have access to energy efficient bulbs. Then at least there is an argument that the non-participants had an opportunity to participate but made a choice not to.

4.1.3.2 No Conservation Scenario

An interesting circumstance might arise if the energy-efficiency program does not appear to generate any decrease in consumption, a.k.a., "conservation." For example, the household may perceive that the savings from the CFL allows them to buy an inexpensive new "bright" halogen fixture. The net result may be that a household may simply consume more lighting for roughly the same price it was paying before—the household has spent its perceived savings on more lighting.

Another common scenario is to replace old inefficient refrigerators with new more efficient refrigerators. Many programs find that consumers "trade-up" from their smaller refrigerators to larger refrigerators with more features (including in-door ice and water dispensers) so that the energy savings is essentially spent by the consumer on more service. [11]

4.1.3.3 Expanding Consumption Opportunities

Refrigerator and freezer replacement programs also pose some interesting questions about whether the existing inefficient appliance will be replaced or not.

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[11] This rebound effect has caused some observers to express the concern that energy "conservation" programs do not lead to conservation, but more consumption. The *Rural Alaska Energy Plan* is focused on providing value to rural households in the form of more efficient supply and end-use of energy. The Plan does not mandate how households should spend the value they receive.

If given a choice, many households may decide to increase their consumption of refrigeration by keeping both the new energy efficient refrigerator and the old less efficient refrigerator—thus expanding their consumption and potentially changing the efficiency of the utility energy supply and lowering or raising costs for non-participants.

Some programs view this as the equivalent of having the consumer choosing to spend their energy savings from the new energy efficient on a "free" used refrigerator that is less efficient. Other programs require the household to surrender the old inefficient refrigerator in order to be eligible to receive the new efficient appliance.[12]

4.1.3.4 Summary of Program Design Considerations

In the end, the goal is to increase end-use energy efficiency and provide net economic benefits to rural Alaska households.

The engineering economy analysis suggests that end-use energy efficiency has significant economic benefits in rural Alaska in light of the high cost of fuel and electricity.

There are two main challenges in program design—one is market data and the other is keeping program overhead low as one attempts to provide service to the many widely dispersed small communities in rural Alaska.

While this and other projects are beginning to collect public data on the penetration of end-use energy efficient lighting and appliances in rural Alaska, publicly available market data remains scarce. There is some evidence that private contractors and energy-efficient appliance retailers have additional data that could enable them to competitively respond to a request for proposals to provide energy efficiency pilot programs.

In addition, several private (profit and non-profit) contractors and energy-efficient appliance retailers appear to be providing low-overhead service to rural Alaska.

Thus, this Plan recommends a multi-year procurement that enables those entities currently providing service to rural Alaska to "bid" on how much support they require in order to provide pilot project end-use energy efficiency programs to rural Alaska communities.

4.2 Recommendations—Summary

Based on initial *market reconnaissance*, MAFA recommends an end-use energy efficiency development program on the order of **$12 million** over roughly four years.

[12] The benefit/cost ratio of an energy-efficient refrigerator replacement program is sensitive to these and many other assumptions. Rather than attempt to map out all of the permutations and guess the potential market response in over 200 rural communities, this Plan recommends multiple pilot programs to test the market and enable a more insightful assessment of the actual benefits and costs that may be achieved in the field.

4.2.1 Program Elements

The rural Alaska household end-use energy efficiency program consists of the following initiatives:

1. Light Bulb Replacement Program	$1.4 million
2. Upgrade/Replace Inefficient Refrigerator Pilot Program	$0.8 million
3. Replace inefficient TV Pilot Program	$0.2 million
4. Replace inefficient Space Heating Systems Pilot Program	$0.8 million
5. Replace electric hot water heaters	$7.5 million
6. Rural School Model Energy Code Program	$0.1 million
Program Sub Total	$10.8 million
Program Administration (5%)	$0.5 million
TOTAL	**$11.3 million**

4.2.2 Procurement Structure

In order to take advantage of economies arising from rural logistical coordination and other potential economies of scale and scope, MAFA recommends that the rural Alaska household end-use energy efficiency program be structured as one large procurement which encourages proposals from in-state entities and partnerships.[13]

The Request for Proposal should be designed to provide rural Alaska households with energy efficiency (including items 1 through 5 of the program elements above) services. The term of the contract should be roughly four years to enable a multi-year deployment and program evaluation.

Proposals should be evaluated based upon 1) Total $ per household of energy efficiency benefits; and 2) Number of households served.

4.3 Appendices

Engineering Economy Calculations

Appendix A: Households—Electric

a. Lighting
b. Refrigerator
c. Freezers
d. Televisions
e. Range (Oven + Cook top)

Appendix B: Households—Space Heating
Appendix C: Households—Water Heating
Appendix D: School Energy Use

[13] See for example, State of Alaska Telecommunications Partnering Plan.

4.4 Appendix A: Households—Electric

4.4.1 Lighting

Assumptions:[14]

25,000 Rural Households; 8 bulbs per household; 1 fluorescent, 7 incandescent

Average hours per bulb = 4 hours/day (April – Sept); 12 hours/day (Oct – March), Annual Average = 8 hours/day; Average Incandescent = 75 Watts

Avg. Avoided Cost of Energy = 16¢/kWh [Golovin Example]

Fluorescent Replacement Bulbs = $6 each; 20 Watts (75 Watt Incandescent Equivalent Lumens); Lamp Life = 8,000 hours

Calculations:

Annual Energy Savings = 8 hours/day * 365 days * (75W-20W) * $0.16/kWh = 160.6 kWh * $0.16/kWh = **$25.70/year/bulb; round it to $25 per bulb per year**

Simple Break-Even:

$6 CFL ÷ $25/year/bulb = 0.24/year = **88 days**[15]

Simple Small Rural Community Program Benefit/Cost Example:

Replace 2 incandescent bulbs per household with new CFL

Energy Benefit:

80 households X 2 bulbs/household X $25/year/bulb X 4 years = **$16,000**

Cost of Program:

Capital = 80 households X 2 bulbs/household X (4 years/2.74 years/bulb) X $6 bulb = **$2803**

Labor = 8 hours X $80 Loaded Labor Rate = **$640**

Air Fare, Lodging, Meals = **$600**

Total Cost = **$4043**

Benefit/Cost = $16,000 ÷ $4043 = 3.96

[200 communities X $16,000 in benefits and $4043 in costs per community = $3.2 million in benefits, $808,600 in costs]

[14] NEI Survey (2001/2002) and MAFA Analysis (2002)

[15] Alternatively, assuming PCE pays 85 percent of the incremental cost of power and receives 85 percent of the benefit of energy savings, the customer pays $6 for a bulb and sees a savings of 15 percent of $25 = $3.75 per year; the simple payback calculation becomes 584 days or roughly 19 months for the consumer. Meanwhile, the PCE program saves roughly $21.25 a year per replaced bulb.

Accelerate Market Penetration Benefit/Cost Example I:

Light Bulb Replacement Program increases market penetration by **4 percent per year** (i.e., from 5 to 9 percent to year CFL adoption rate)

Assume program covers 20 communities in one year

20 communities X 100 households/community X 7 incandescent bulbs/household X 4 percent incremental replacement rate = **560 bulbs/year**

Incremental Benefit

560 bulbs/year X $25/bulb/year X 4 years = **$56,000**

Incremental Cost =

Capital = 20 communities X 100 households/community X 2 bulbs/household X (4 years/2.74 years/bulb) X $6 bulb = **$35,036**[16]

Labor = 20 X 8 hours X $80 Loaded Labor Rate = **$12,800**

Air Fare, Lodging, Meals = 20 X $600 = **$12,000**

Incremental Cost = **$59,836**

Benefit/Cost = 0.94

Accelerate Market Penetration Benefit/Cost Example II:

Light Bulb Replacement Program increases market penetration by **8 percent per year** (i.e., from 5 to 13 percent to year CFL adoption rate)

Assume program covers 20 communities in one year

20 communities X 100 households/community X 7 incandescent bulbs/household X 8 percent incremental replacement rate = **1120 bulbs/year**

Incremental Benefit

1120 bulbs/year X $25/bulb/year X 4 years = **$112,000**

Incremental Cost =

Capital = 20 communities X 100 households/community X 2 bulbs/household X (4 years/2.74 years/bulb) X $6 bulb = **$35,036**[17]

Labor = 20 communities X 8 hours X $80 Loaded Labor Rate = **$12,800**

Air Fare, Lodging, Meals = 20 communities X $600 = **$12,000**

Incremental Cost = **$59,836**

Benefit/Cost = 1.87

The economic benefits of new lighting remain very high. In short, the energy efficiency of new compact CFLs is *very high* relative to incandescent lighting.

[16] Please note this assumes 5,839 bulbs being replaced, 560 of which are "incremental" and 5,279 of which are "free riders" that would have been changed anyway without the light bulb program.

[17] Please note this assumes 5,839 bulbs being replaced, 1,120 of which are "incremental" and 4,719 of which are "free riders" that would have been changed anyway without the light bulb program.

Even if one assumes that 80 percent of the CFLs are distributed to households that would have bought them without the program (the "free riders"), the program can still provide net economic benefits.

Assume a statewide replacement program with approximately 200 communities X $7,000 per community = **$1.4 million** over four years.

4.4.2 Household Refrigeration

Assumptions:[18]

25,000 rural households; 1.2 refrigerators per household

Aggregate Average Energy Use of Currently Deployed Refrigerators = 950 kWh/year (Aggregate Average Rural Alaska Vintage estimated at late 1980s); 40 - 52 kWh/year per cubic foot of capacity

New Refrigerators (2001 Standard) = 500 kWh/year (avg.); range from 22 – 32kWh/year per cubic foot of capacity

New *Energy Star* Refrigerators (2001Guidelines) = 10 to 20 percent more efficient than 2001 National Appliance Standard; range from 20 – 29 kWh per year per cubic foot of capacity

Cost of New *Non*-Energy Star Refrigerator = $850

Cost of New *Energy Star* Refrigerator = $900

Alternatives:

Program 1: Replace old inefficient refrigerators prior to end of normal life ("Air Drop" new Energy Star refrigerators)

Program 2: Provide credit toward purchase of new *Energy Star* refrigerator (presume that new purchase is choice between new refrigerator and new *Energy Star* refrigerator)

Calculations:

Annual Energy Savings$_1$ = (950 – 450 kWh/year) * 16¢/kWh = $80/year

Annual Energy Savings$_2$ = (500 - 425 kWh/year) * 16¢/kWh = $12/year

Simple Break-Even:

Break-Even$_1$ = $900 ÷ $80 **= 11.25 years**[19]

Break-Even$_2$ = $50 ÷ $12 **= 4.17 years**[20]

[18] NEI Survey (2001/2002) and MAFA Analysis (2002)

[19] Assuming PCE pays 85 percent of the incremental cost of power and receives 85 percent of the benefit of energy savings, the customer pays $900 for a new refrigerator and sees a savings of 15 percent of $80 = $12 per year; the simple payback calculation becomes roughly *75 years* for the consumer. Meanwhile, the PCE program saves roughly $68 a year when a new energy efficient refrigerator replaces a less efficient refrigerator.

[20] Alternatively, assuming PCE pays 85 percent of the incremental cost of power and receives 85 percent of the benefit of energy savings, the customer pays $50 on the increment for a new *Energy Star* refrigerator and sees a savings of 15 percent of $12 = $1.80 per year; the simple payback calculation becomes roughly *28 years* for

1: Replace Existing Refrigerators in Community with New Energy Star Refrigerators

<u>Energy Benefit:</u>

Avoided Cost = 120 households X 90% Penetration X $80 per year **= $8,640**

<u>Cost of Program:</u>

Capital = 120 households X 90% X $900 per refrigerator = $97,200

Labor = $640

Air Fare, Lodging, Meals = $600

Total Cost = **$98,440**

Benefit/Cost [Zero Discount] = ($8,760 * 15 years) ÷ $98,440 = **1.33**

Benefit/Cost [5 percent discount] = 0.92

2: Provide Credit toward purchase of New Energy Star Refrigerator when household is looking to buy a new refrigerator

<u>Energy Benefit:</u>

Avoided Cost = 120 households X 7% Penetration X $12 per year **= $100.80/year; call it $100 per year**

<u>Cost of Program:</u>

Capital = 120 households X 7% X $50 per refrigerator = $420

Labor = $80

Air Fare, Lodging, Meals = $0

Total Cost = **$500**

Benefit/Cost [Zero Discount] = $100 * 15 years ÷ $500 = **3.00**

Benefit/Cost [5 percent discount] = 2.18

While it is possible to develop scenarios where the program benefits exceed the costs, the economics of refrigerator replacement programs are sensitive to a number of market assumptions including:

- free riders—number of new energy-efficient refrigerator purchases that would have been made without the program in place
- age and efficiency of old fridge vs. new fridge
- size of old fridge, size of new fridge, features (in-door water/ice)
- replacement of old fridge at the end of its life or prior
- disposal costs of old fridge
- purchase price of new fridge vs. new energy star efficient fridge vs. new ultra high efficiency fridge[21]

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the consumer. Meanwhile, the PCE program saves roughly $12.75 a year when a new energy star refrigerator is purchased instead of a new non-energy star refrigerator.

[21] Please see Northern Arizona Wind & Sun, “Appliances” for a discussion of the ConServe and SunFrost “ultra high” efficiency refrigerators and freezers.

Therefore, given the wide range of uncertainty, some combination of regional pilot programs to test these parameters may be the most effective way to expand energy efficiency alternatives for rural households.

For example, a combination of a voucher and replacement program with an evaluation component incorporated into each phase may be appropriate.

Energy Star Voucher:

Provide a credit worth $50 toward the purchase of a new Energy Star refrigerator in exchange for old refrigerators that have been properly disposed. Provide eight communities with a $20,000 refrigerator disposal grant and $50 vouchers X 120 households X 15 percent penetration. **Total $200,000**. (including program evaluation)

Replacement:

Provide four communities with a $150,000 refrigerator replacement program grant ($1250 per household X 120 households X 4 communities). **Total $600,000**.

4.4.3 Household Freezers

Assumptions:

59 percent of rural households appear to have a freezer separate from upright combination Refrigerator/Freezer units.

Survey responses did not distinguish between chest style and upright freezer; though anecdotal evidence suggests most are chest style manual defrost.

25,000 households X 59% X 4.5 cubic feet per person X 3.2 people per household ≈ 220,000 cubic feet of household freezer capacity

Performance of freezers in the field:[22]

Chest (Manual Defrost) (c. 70s, 80s): 39 – 54 kWh per year per cubic foot

Performance of currently available freezers:[23]

Upright Manual Defrost: 31 - 48 kWh per year per cubic foot

Upright Automatic Defrost: 43 – 61 kWh per year per cubic foot

Chest (Manual Defrost): 25.3 - 36 kWh per year per cubic foot

Compare 14.8 cubic foot chest freezers ($500 delivered)
Existing = 581 kWh/year
New = 437 kWh/year

[22] Estimate based upon anecdotal evidence from 1970s and 1980s freezer energy efficiency.

[23] Natural Resources Canada, Office of Energy Efficiency, EnerGuide Appliance Directory, 2001

Calculations:

Annual Energy Savings = (581 - 437kWh/year) * 16¢/kWh = $23.04/year; call it $23.

Simple Break-Even:

Break-Even = $500/$23 = **22 years**[24]

Energy Benefit:

120 households X 59% freezers X 90% participation X $23 per year = **$1466 per year**

Cost of Program:

Capital = 120 X 59% X 90% X $500 = **$31,860**

Labor = **$640**

Air Fare, Lodging, Meals = **$600**

Total Cost = **$33,100**

Benefit/Cost [Zero Discount] = $1466 X 15 years ÷ $31,300 = **0.70**

While it is possible to develop scenarios where the program benefits exceed the costs, the economics of freezer replacement programs ***do not appear favorable*** and are sensitive to a number of market assumptions including:

- free riders—number of new energy-efficient freezer purchases that would have been made without the program in place
- age and efficiency of old freezer vs. new freezer
- life of freezers
- size of old freezer, size of new freezer, features (manual defrost vs. frost-free)
- replacement of old freezer at the end of its life or prior
- disposal costs of old freezer
- purchase price of new freezer vs. new energy efficient freezer
- whether or not an energy efficient *community freezer* facility is an alternative (especially given low ground temperatures and the potential to use "excess" wind energy to store up cold energy)

Therefore, given the wide range of uncertainty, and the apparently unfavorable economics, no freezer voucher or replacement program is recommended at this time.

[24] Alternatively, assuming PCE pays 85 percent of the incremental cost of power and receives 85 percent of the benefit of energy savings, the customer pays $500 for a new freezer and sees a savings of 15 percent of $23 = $3.45 per year; the simple payback calculation becomes roughly *145 years* for the consumer. Meanwhile, the PCE program saves roughly $19.55 a year if the new freezer is replacing an old one.

4.4.4 Televisions

Assumptions:

25,000 rural households; 0.98 televisions per household; 8 hours per day in use

Aggregate Average Energy Use of Currently Deployed Televisions

In-Use: 120 watts

Standby: 10 watts

New TVs

In-Use: 75 watts

Standby: 6.0 watts

New *Energy Star* TV (2001 Guidelines)

In-Use: 71.5 watts

Standby: 2.5

1. Replace existing inefficient with new Energy Star TV
2. Encourage purchase of Energy Star TV at time of new purchase

Calculations:

Annual Energy Savings$_1$ = (8 hours per day X (120-71.5 watts) + 16 hours per day X (10-2.5 watts)) X 365 days X 0.02c/wh = **$37.08 per year**

Annual Energy Savings$_2$ = (8 hours per day X (75-71.5 watts) + 16 hours per day X (6.0-2.5 watts)) X 365 days X 0.02c/wh = **6.13 per year**

Simple Break-Even:

Break-Even$_1$ = $300/$37.08 = 8.09 years[25]

Break-Even$_2$ = $40/$6.13 = 6.53 years

Simple Small Rural Community Program Benefit/Cost:

Energy Benefit:

120 households X 98% X $37 per set per year = **$4351/year**

Cost of Program:

Capital = 120 X 98% X $300 = **$35,280**

Labor = **$160**

[25] Alternatively, assuming PCE pays 85 percent of the incremental cost of power and receives 85 percent of the benefit of energy savings, the customer pays $300 for a new Energy Star TV and sees a savings of 15 percent of $37 = $5.56 per year; the simple payback calculation becomes roughly *54 years* for the consumer. Meanwhile, the PCE program saves roughly $31.50 a year by replacing the old inefficient TV.

Air Fare, Lodging, Meals = **$400**

Total Cost = **$35,840**

Benefit/Cost = $4351 X 11 years ÷ $35,840 = **1.34**

Benefit/Cost [5% discount rate] = **1.01**

While it is possible to develop scenarios where the program benefits exceed the costs, the economics of television replacement programs are sensitive to a number of market assumptions including:

- free riders—number of new energy efficient television purchases that would have been made without the program in place
- whether the "energy savings" is spent on upgrading to larger models with more features

It may be more appropriate to explore a pilot program before pursuing any large scale replacement program.

Pilot programs

Eight communities X 120 households per community X $50 voucher on new purchase = $48,000 ≈ **$50,000**

Four communities X 120 households per community X $300 voucher = $144,000 ≈ **$150,000**

Program Evaluation = $25,000

Total = $225,000

4.4.5 Cook top + Oven

Assumptions:

25,000 households	Annual Energy Use[26]
40 percent Propane	4.6 MMBTU/year per cooktop/oven
45 percent Electric	4.2 MMBTU/year per cooktop/oven
5 percent wood/oil	?
10 percent Unknown	?

Propane Heating Value = 91,600 BTU/gallon; Propane Cooking Efficiency = 70%

Propane Price = $3.00 per gallon - $4.00 per gallon

Electric Heating Value = 3413 BTU/kWh; Electric Heating Efficiency = 95%

[26] Estimates based on Texas Railroad Commission Propane vs. Electric Range Comparisons, 2000. Annual cost of Propane = $86, Annual Cost of Electricity = $98; Propane = $1.20/gallon; Electricity = 8 cents/kWh.

Calculations:

Convert Electric Range (Oven + Cook Top) to Propane Range

> Electric Range Annual Cost = 16c/kWh X 4.2 MMBTU/year ÷ 3413 BTU/kWh ÷ 95% Efficiency = $0.16/kWh X 1295 kWh/year = **$207/year**
>
> Propane Range Annual Cost **Low** = $3.00/gallon X 4.6 MMBtu/year ÷ 91,600 BTU/gallon ÷ 70% Efficiency = $3.00/gallon X 72 gallons/year = **$216/year**
>
> Propane Range Annual Cost **High** = $4.00/gallon X 4.6 MMBtu/year ÷ 91,600 BTU/gallon ÷ 70% Efficiency = $4.00/gallon X 72 gallons/year = **$288/year**

Annual Energy Savings = **-$81/year (high propane cost) to -$9/year (low propane cost)**

It appears that propane costs more than electricity for the assumptions under consideration.

While it is possible to develop scenarios where the program benefits exceed the costs, the economics of electric range replacement programs are sensitive to a number of market assumptions including:

- relative price of propane and electricity ($/MMBtu)
- household cooking techniques— studies of end-use cooking indicate a wide variation (over 50 percent between different cooks on similar recipes) between cooking techniques with respect to energy use; suggesting that modest efforts to change cooking practice may yield more incremental benefits than changing cooking technology from electric to propane[27]

In addition, the use of propane fuel in household cooking raises indoor air quality issues including:

- household sensitivity to moisture due to propane cooking (many households may desire additional moisture, especially given the cold dry air of winter, while others may wish to avoid it)
- household sensitivity to molds that may grow more vigorously in moist environments
- household health concerns have been raised by converting from electric to propane ranges due to increased combustion products in the indoor air (CO_2)

As a result, there may be some potential for a pilot program in communities where:

- the incremental cost of electricity is relatively high compared to propane
- households desire more moisture in the air
- local/regional community health officials do not believe that the moisture and increased combustion products due to propane cooking pose a health threat

It is unknown at this time whether there are any communities that would meet these criteria to qualify for a pilot program in converting electric to propane ranges.

[27] See for example, comments filed in US DOE, Office of Energy Efficiency and Renewable Energy, Energy Conservation Program for Consumer Products: Energy Conservation Standards for Electric Cooking Products, summarized at Federal Register 48038-48057, Tuesday, September 8, 1998.

4.5 Appendix B: Household Space Heating

Assumptions:

Table 4-3. Estimated Annual Fuel Consumption by Heating Source Type

Heating Source Type	Percent of Market[28]	Est. Annual Fuel Consumption[29] (Gallons #2 Fuel Oil)
Central Boilers/Furnaces	40	825
Efficient Direct Vent Heaters (e.g., Monitor, Toyo, Rinnai)	44	675[30]
Pot Burner/Cook Stove	2	1130
Other (wood stove)	14	?
Weighted Avg.		Approx 760 gallons

Table 4-4. Fuel Conversion Efficiency & Gallon Savings of Direct Vent Heaters

	Fuel Efficiency (%)	Annual Gallons of Fuel Saved with Efficient Direct Vent Heaters
Efficient Direct Vent Heaters	92	0
Central Boilers/Furnaces	75	150[31]
Pot Burner/Cook Stove	55	450

Residential Heating Oil = $1.50 per gallon [Range from $1.00 to $3.00 per gallon]

Initial Capital Cost of New Efficient Direct Vent Heater Installed = $1800[32]

Calculations:

Annual Energy Savings

Direct Vent Replace Central Boiler/Furnace = $1.50 X 150 gallons **= $225/year**

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[28] NEI End-Use Survey (2001)

[29] Interpolation between NEI End-Use Survey (2001) results and weatherization contractors.

[30] Please note that this comparison assumes that the direct vent heater is providing approximately the same net BTU of heat to the household over the year compared to a central boiler/furnace system. It may be more typical to find that households who have converted to direct vent heater have achieved fuel savings that exceed these because they are willing to accept cooler rooms away from the main room that is heated by the direct vent unit.

[31] This assumes that the efficient direct vent heater will provide an equivalent amount of BTU heating as the other systems. As noted above, some households are able to achieve additional fuel savings due to accepting reduced temperatures in some rooms. While this may be an increase in fuel efficiency as measured by comfort, this additional fuel savings does not represent an increase in fuel conversion efficiency. Thus, to provide a reasonably conservative estimate of potential economic savings of converting to efficient direct vent heaters, the fuel savings associated with reduced temperatures in some rooms is not included in the analysis.

[32] Toyo Stove in Nome plus freight to small village plus installation.

Direct Vent Replace Pot Burner/Cook Stove = $1.50 X 450 gallons = **$675/year**

Simple Break-Even:

Direct Vent Replace Central Boiler/Furnace = $1800/$225 = **8 years**

Direct Vent Replace Pot Burner/Cook Stove = $1800/$675 = **2.67 years**

Program Description:

Replace existing central boilers/furnaces and pot burner/cook stoves in rural village with 120 households

<u>Energy Benefit:</u>

40% X 120 households X $225/household/year = $10,800

2% X 120 households X $675/household/year = $1,620

Total Annual Energy Benefit = $12,420 community per year

Total Energy Benefit = 10 years = **$124,420**

<u>Cost of Program:</u>

Capital (including installation labor) = $1800/household X 51 units = **$91,800**

Overhead Labor = **$640 (8 hours X $80)**

Air Fare, Lodging, Meals = **$2,460 ($300 RTAF + ($90/p-day X 24 days)**

Total Cost = **$94,900**

Benefit/Cost [zero discount] = **1.31**

Benefit/Cost [5 percent discount] = **1.06**

While it is possible to develop scenarios where the program benefits exceed the costs, the economics of heating unit replacement programs are sensitive to a number of market assumptions including:

- free riders – number of new energy efficient direct vent heater purchases that would have been made without the program in place
- Price of residential fuel oil
- Relative performance of existing central boiler/furnace to new direct vent heating units

A pilot program may be more appropriate to evaluate the potential benefit cost ratio of heating replacement program compared to existing market trends absent a new program.

Eight communities X $94,900 per community = $760,000 ≈ **$800,000 (including evaluation of free riders)**

4.6 Appendix C: Household Water Heating

Assumptions:

52 percent of households have a water heater (13,000 households) [RurALCAP Data]

43 percent of households with water heater have electric water heat (5600 households) [RurALCAP Data]

22 percent of rural households have electric hot water heaters

Table 4-5. Water Heater Cost Comparisons

	Annual Energy Requirements[33]	Installed Cost	Annual Energy Costs 16¢/kWh $1.50/gallon	Annual Energy Savings of On-Demand Water Heater
Electric – Tank Water Heater	5690 kWh	$400	$910	$700
Oil – Tank Water Heater	180 gallons	$1500	$270	$60
Toyotomi On-Demand Water Heater	140 gallons	$1500	$210	$0

Calculations:

Simple Break-Even:

Oil Tank Water Heater to Replace Electric Tank Water Heater =

Cost = $1500

Benefit = ($910-$270) = $640

Simple Break-Even = $1500/$640 = **2.34 years**

On-Demand Water Heater to Replace Electric Tank Water Heater =

Cost = $1500

Benefit = ($910 - $210) = $700

Simple Break-Even = $1500/$700 = **2.14 years**

On-Demand Water Heater to Replace Oil Tank Water Heater = 1500/60 = **25 years**

Incremental Capital = $0; $60 per year *net* energy savings if an Oil Tank Water Heater at the end of its life is replaced with on-demand water heater

Energy Benefit (Replace Electric Hot Water Heaters):

[33] AVEC Estimates

120 households X 22% Electric Water Heaters X $700 = $18,480

Total Community Benefit = **$18,480 per year**

Total Community Benefit (10 years) = **$184,800**

<u>Cost of Program:</u>

Capital = 120 X 22% X $1500 = **$39,600**

Labor = **$640**

Air Fare, Lodging, Meals = **$1,110 ($300 + $90/day X 9)**

Total Cost = **$41,350**

Benefit/Cost [Zero Discount] = **4.47**

Assume a statewide replacement program of electric water heaters.

Approximately 180 communities X $42,000 per community = **$7.5 million** over four years.

Aggregate Benefits = 180 X $184,800 = $33 million over ten years.

4.7 Appendix D: School Energy Use

Assumptions:

It appears that roughly 4.1 million square feet of school buildings existing in the PCE-eligible communities in rural Alaska. Based on anecdotal evidence, the average electrical consumption is estimated at 12kWh/square foot/year. Average heating fuel consumption is estimated at 1.2gallons/square foot/year.

Thus, in aggregate, rural Alaska school buildings consume roughly:

Electricity	49,200,000 kWh/year	$14.8 million/year
Heating Fuel	5,000,000 gallons/year	$ 7.5 million/year

Based on school buildings constructed under the Canadian Energy Code in the Yukon Territories, it appears that energy consumption for *new* rural schools in Alaska can be reduced on the order of 30 to 50 percent based on anecdotal evidence of similar climatic and school usage requirements as those found in the Yukon Territories.

Based on a school size of 16,000 square feet, annual energy savings on the order of

(12 kWh/sq ft/year – 8 kWh/sq ft/year) * (16,000 sq ft) * 20 c/kWh = $12,800/year

+

(1.2 – 0.8 gallons/sq ft/year) * (16,000 sq ft) * $1.20/gallon = $7,680/year

= Annual Energy Savings = $20,480/year

Annual energy savings on the order of $20,000 per school is sufficient to justify **capital and program costs of $280,000 per school**. (5 percent discount rate, 25 year life)

Recommend funding a code development group with $100,000 in contract and associated support to develop a model energy code for rural Alaska schools.